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Ishikawa

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[54] **AC GENERATOR FOR VEHICLE HAVING COMBINED STRUCTURE OF FIELD COIL AND PERMANENT MAGNET**

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[73] Assignee: **Denso Corporation**, Kariya, Japan

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[51] **Int. Cl.**[6] **H02K 1/122**

[52] **U.S. Cl.** **310/263**; 310/181; 310/156

[58] **Field of Search** 310/181, 263

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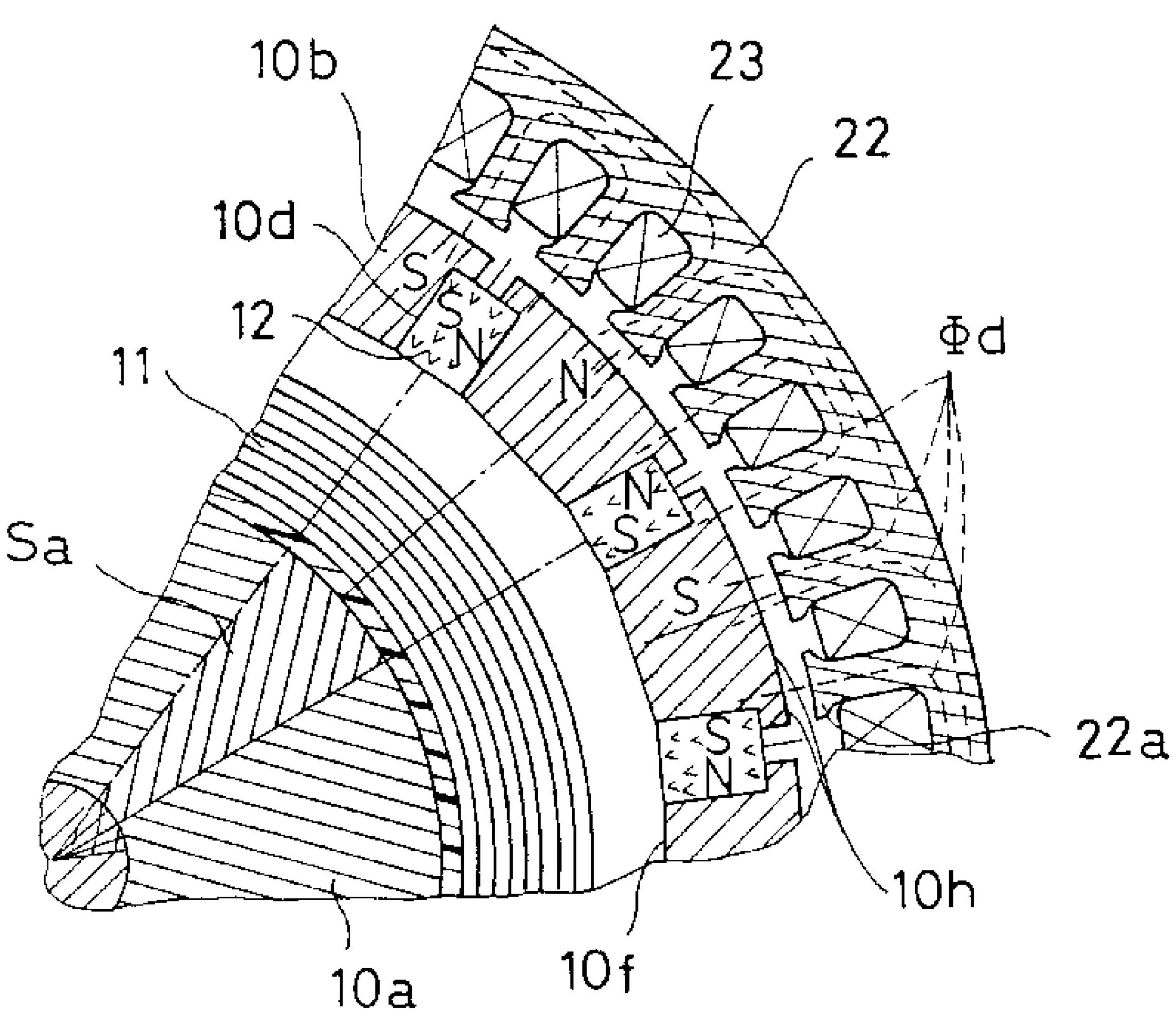
Assistant Examiner—Karl I. Eizo Tamai
Attorney, Agent, or Firm—Cushman Darby & Cushman IP Group of Pillsbury Madison & Sutro LLP

[57] **ABSTRACT**

An AC generator has a rotor with permanent magnets disposed between claw poles. The rotor has Lundell-type pole cores having a boss portion where a field coil is wound and claw poles. The permanent magnets are sintered ferrite magnets and disposed between opposite side surfaces of the adjacent claw poles and magnetized to have the same magnetic pole as the claw pole adjacent thereto. A ratio between the cross-sectional area per pole of the magnetic path of the boss portion and peripheral surface area of the claw poles facing the teeth of the stator core is designed to be between 70% to 120%.

7 Claims, 4 Drawing Sheets



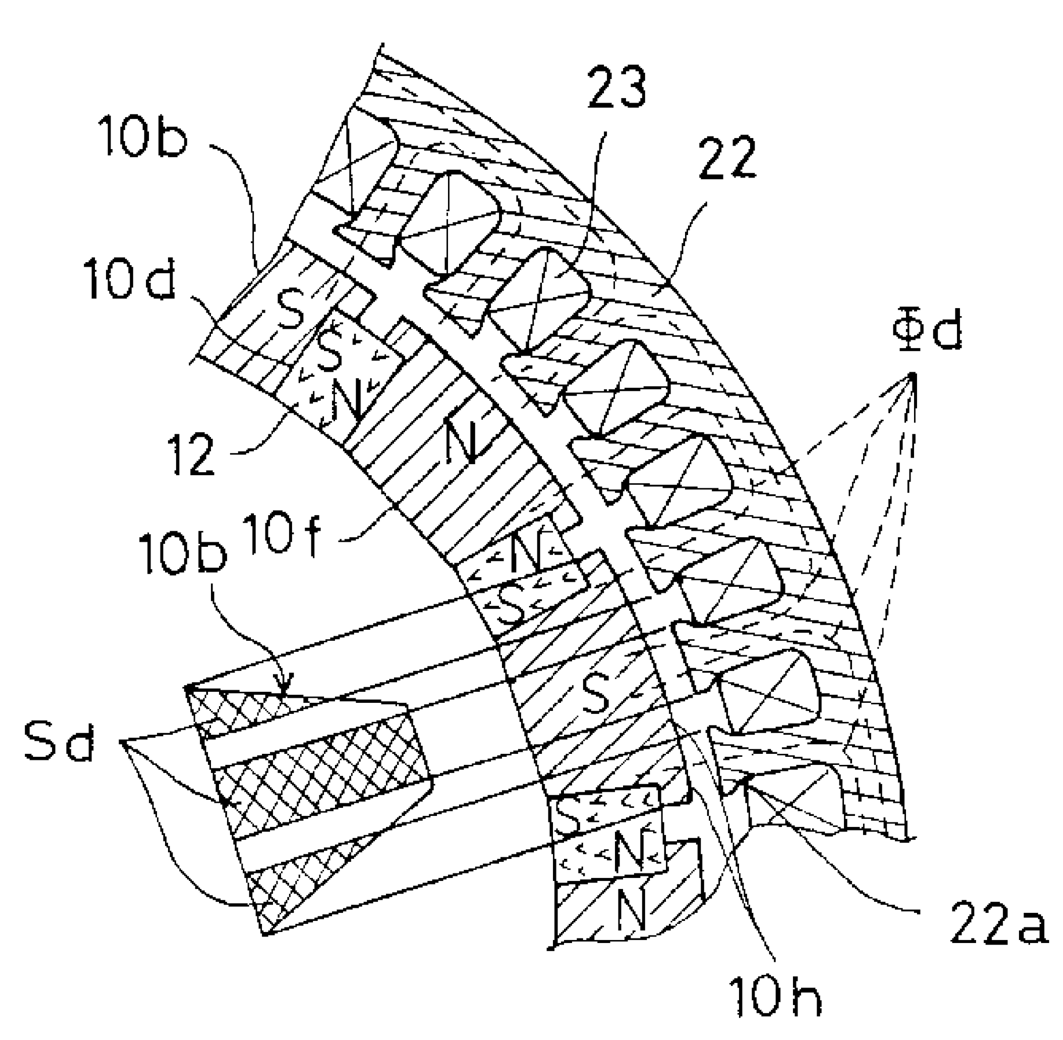


FIG. 1

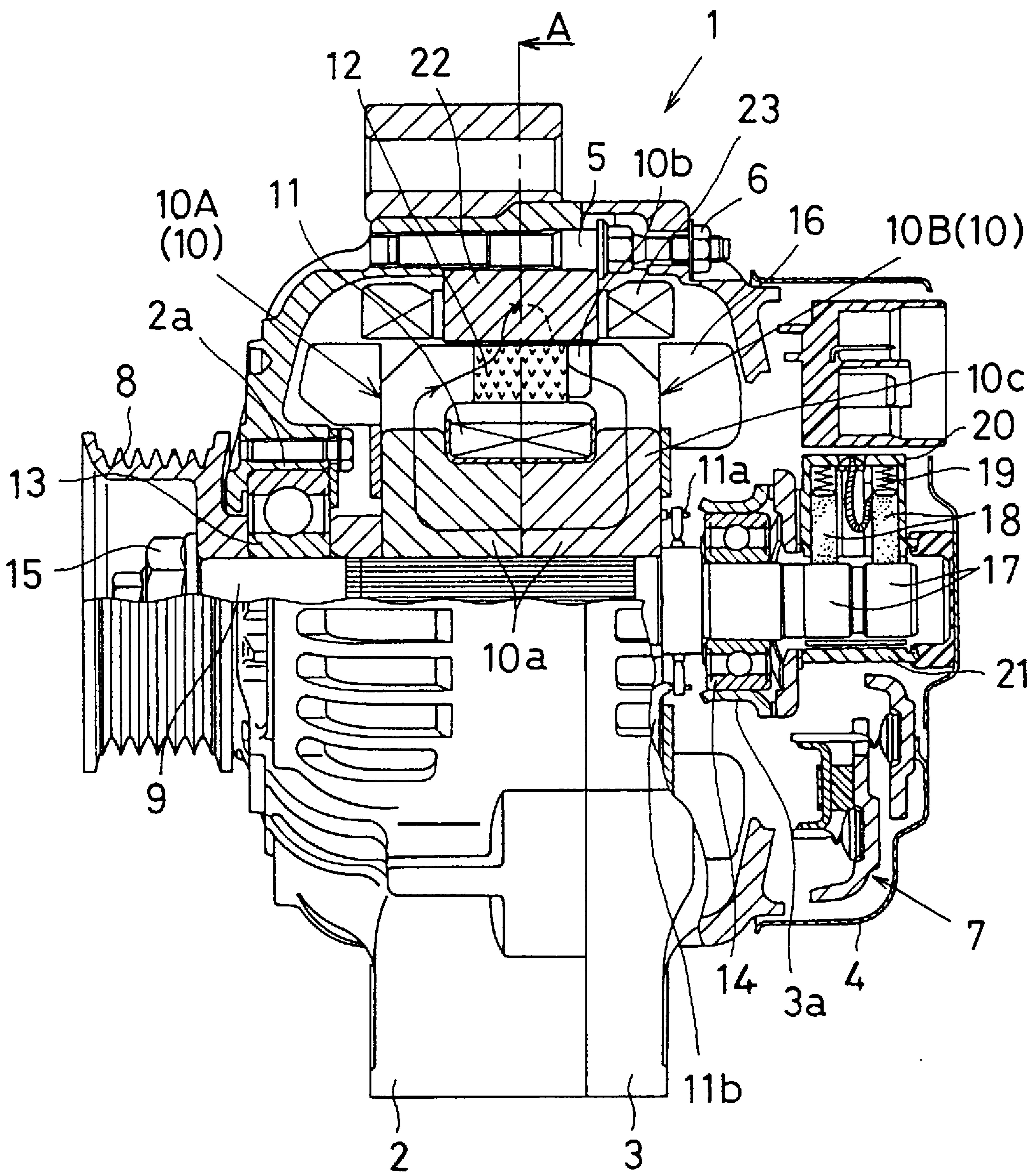

A
1
12
22
23
5
10b
6
10A
(10)
11
16
10B(10)
2a
8
10c
20
13
11a
19
18
15
17
10a
21
9
7
14
3a
4
11b
2
3

FIG. 2

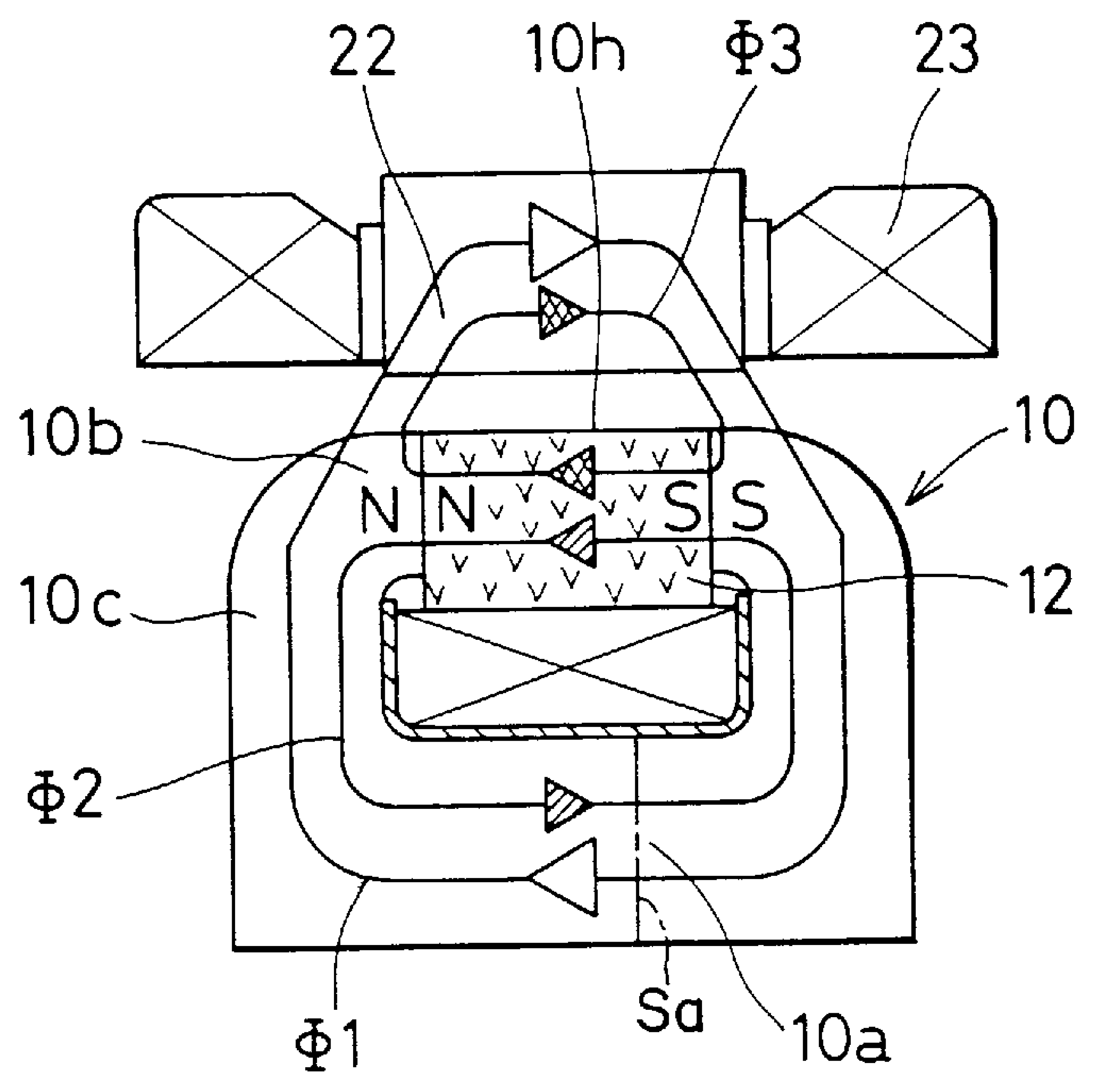

22
10h
Φ3
23
10b
10
N
N
S
S
10c
12
Φ2
Φ1
Sa
10a

FIG. 3

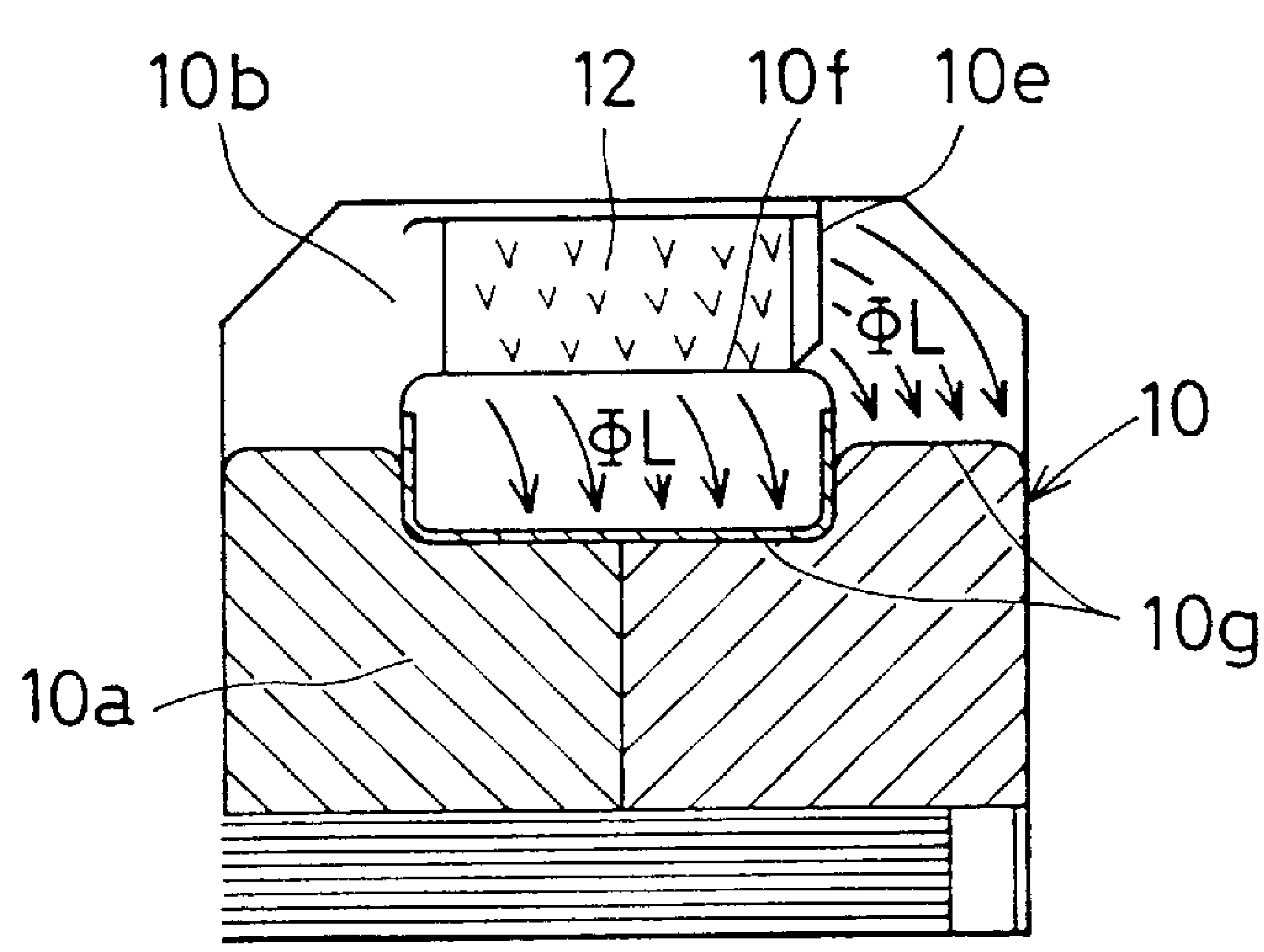

10b
12
10f
10e
ΦL
ΦL
10
10g
10a

FIG. 4

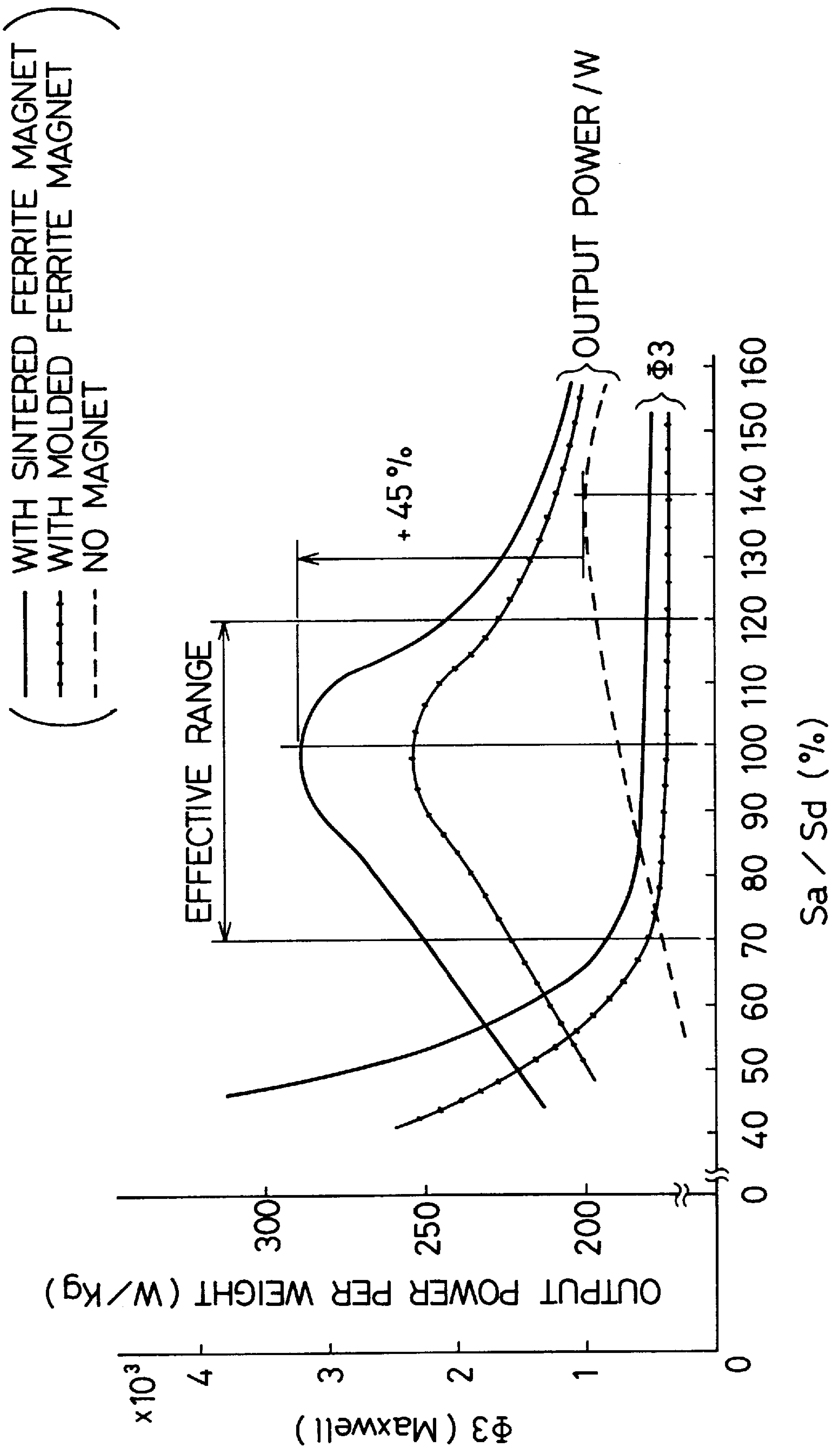

WITH SINTERED FERRITE MAGNET
WITH MOLDED FERRITE MAGNET
NO MAGNET
OUTPUT POWER / W
Φ3
+45%
EFFECTIVE RANGE
OUTPUT POWER PER WEIGHT (W/Kg)
300
250
200
Φ3 (Maxwell)
x10³
4
3
2
1
0
40
50
60
70
80
90
100
110
120
130
140
150
160
Sa / Sd (%)

FIG. 5

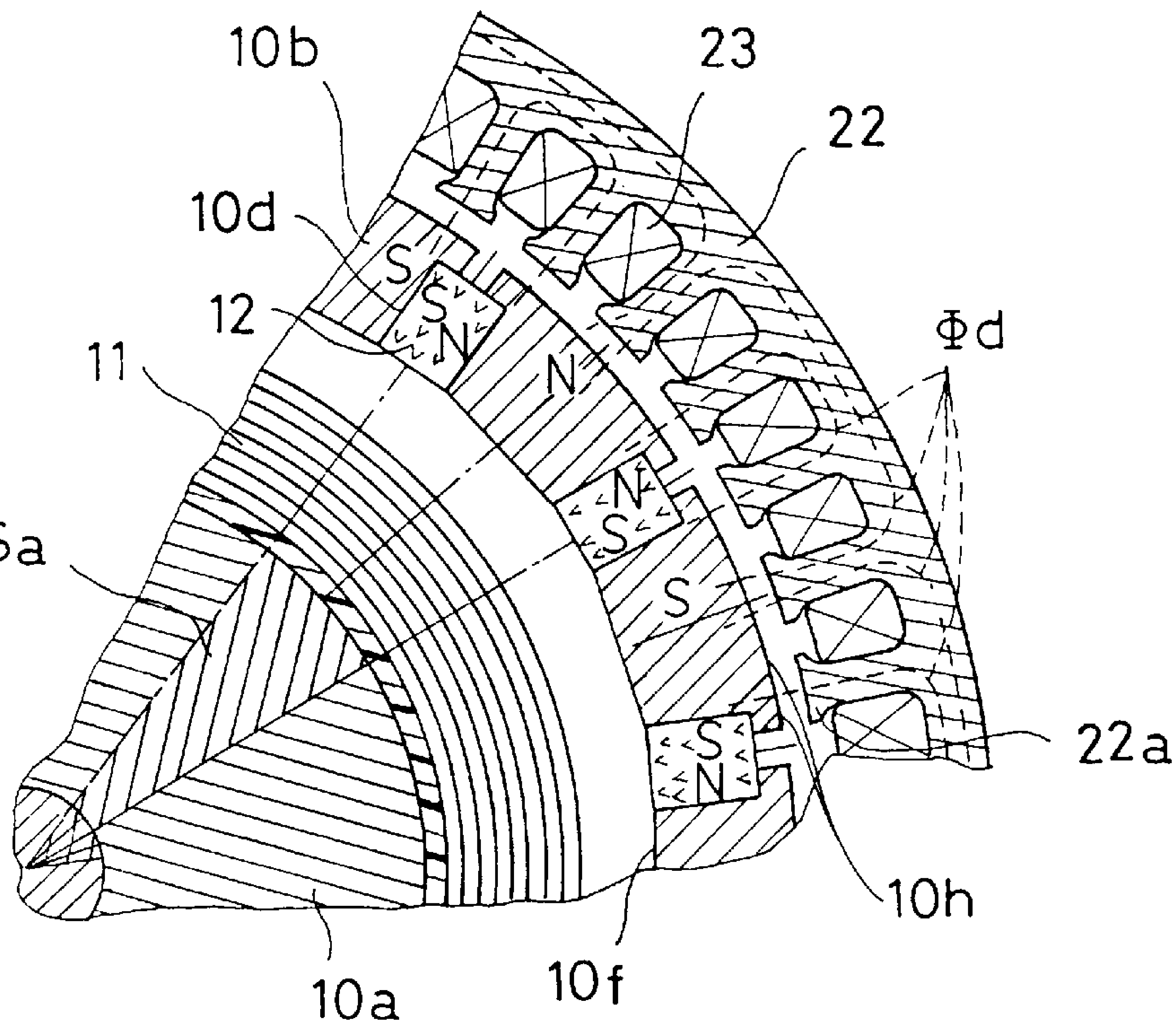
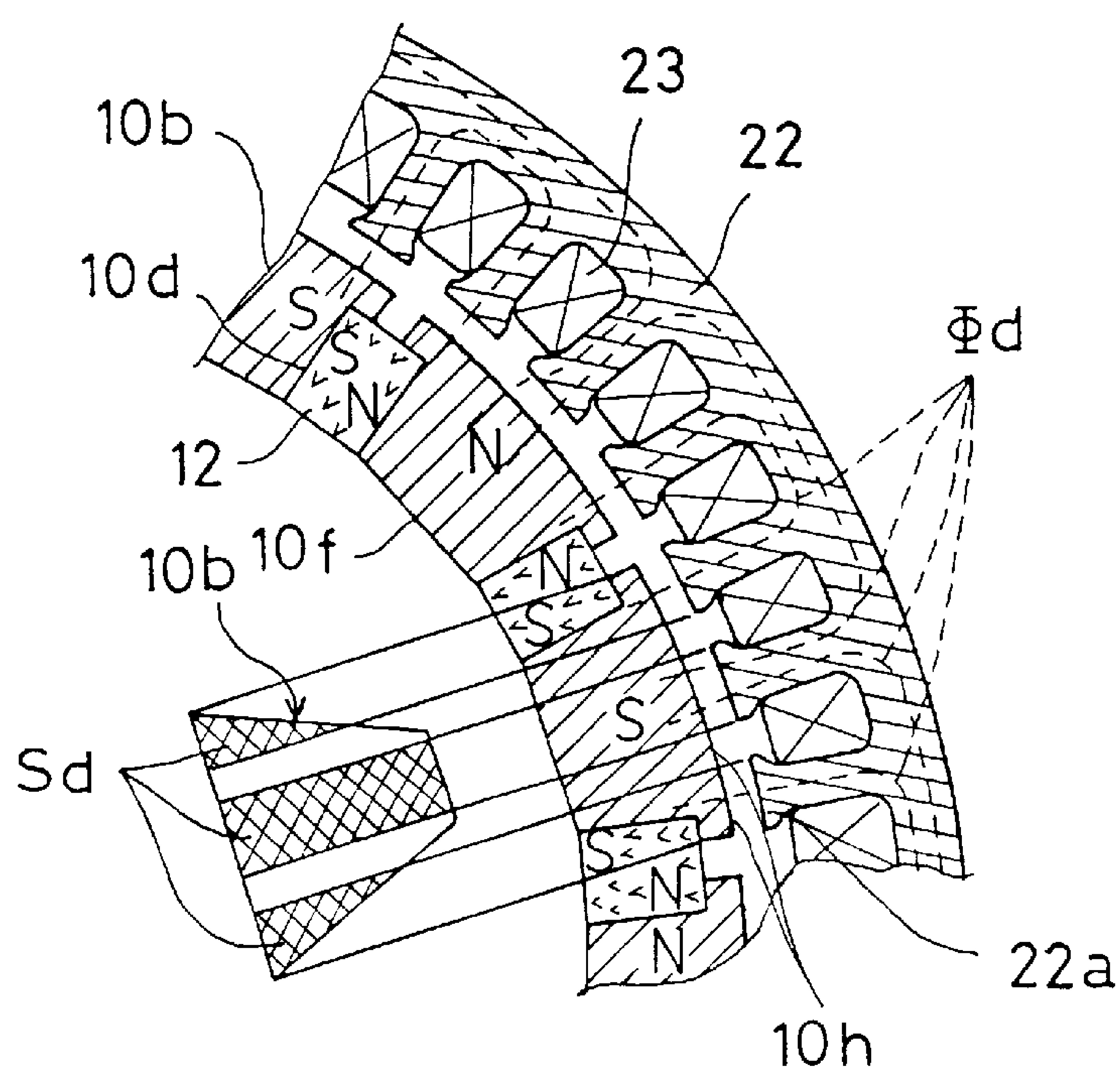

10b
23
22
10d
S
S
N
12
N
Φd
11
N
S
Sa
S
S
N
22a
10h
10a
10f

FIG. 6


23
10b
22
10d
S
S
N
Φd
12
N
10b
10f
N
S
S
Sd
S
N
N
22a
10h

AC GENERATOR FOR VEHICLE HAVING COMBINED STRUCTURE OF FIELD COIL AND PERMANENT MAGNET

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an AC generator for a vehicle which is driven by an engine and supplies an AC power.

2. Description of the Related Art

A conventional AC generator for a vehicle has a magnetic-field-rotor with a so called Lundell-type pole core and a field coil. A part of magnetic flux generated in the pole cores leaks through the adjacent claw poles. Therefore, an amount of the magnetic flux passing through the magnetic path of the rotor is usually larger than an amount of the magnetic flux passing through the peripheral surface of the claw poles. In general, the ratio between the cross-sectional area of the magnetic path of the winding portion of the claw poles and the area of the peripheral surface of the claw poles is approximately 140% because the cross-sectional area of the magnetic path is designed to be proportional to the amount of the magnetic flux in view of reducing the rotor weight and increasing the output power per weight thereof.

In order to increase the output power, permanent magnets are disposed between the adjacent claw poles thereby reducing leakage of the magnetic flux. However, if the magnetic flux of the permanent magnet is added to the stator, an excessive voltage may be generated even when the field coil is not energized.

In order to solve such a problem, an optimum ratio between the area of the claw poles where the permanent magnet is in contact with and the base cross-sectional area of each of the claw poles has been proposed in JPA 4-255451.

However, if such a ratio between the cross-sectional-area of the winding portion and the peripheral-surface-area of the claw poles is applied to the rotor having the permanent magnet between the claw poles, the cross-sectional area of the magnetic path is not properly formed because the magnetic flux of the permanent magnet is not taken into account. Therefore, the weight of the rotor is not reduced and the power per rotor-weight does not become maximum.

On the other hand, even if the rotor has the permanent magnet between the claw poles, the cross-sectional area of the magnetic path only includes the portion of the claw poles in contact with the permanent magnet and the base portion of claw poles and the weight of the claw poles is smaller than that of the stator. Therefore, the rotor weight can not be reduced sufficiently.

SUMMARY OF THE INVENTION

The present invention has been made in view of the above circumstances, and an object of the present invention is to provide an economical AC generator for a vehicle which has a rotor with a permanent magnet between the claw poles, generates an increased power per weight of the rotor with less amount of material.

According to one aspect of the invention, a cross-sectional area of magnetic path of the pole core per each pole is between 70% and 120% of peripheral surface area of each of said claw poles facing said teeth. Therefore, the magnetic-flux-density of each magnetic path becomes even. According to a test, when the ratio of the above areas exceeds 120%, power increase of the rotor per weight drops steeply. On the

other hand, when it decreases less than 70%, the excessive generator voltage with the non-excited field increases steeply. Therefore, the effective magnetic flux is kept at the same level as the conventional generator and the rotor weight is reduced, or the rotor weight is kept at the same level as the conventional generator and the effective magnetic flux is increased, resulting in increase of the power per weight.

According to another aspect of the present invention, sintered ferrite magnets which are widely available are used.

According to another aspect of the present invention, a centrifugal-force-resistive generator is provided by using molded ferrite magnet because of the low specific gravity thereof. The molded ferrite magnet forms a circular member having a plurality of magnetized poles and is disposed between the claw poles. Therefore, it is assembled with ease.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, features and characteristics of the present invention as well as the functions of related parts of the present invention will become clear from a study of the following detailed description, the appended claims and the drawings. In the drawings:

FIG. **1** is a cross-sectional view illustrating an AC generator for a vehicle;

FIG. **2** is a schematic diagram showing magnetic flux generated by a field coil and magnetic flux generated by a permanent magnet;

FIG. **3** is a schematic cross-sectional view illustrating a rotor with leakage magnetic flux;

FIG. **4** is a graph showing relationship between output power of the rotor per pole as well as effective magnetic flux reaching the stator when no field current is supplied and ratio between the cross-sectional area of the magnetic path and peripheral surface of the claw poles;

FIG. **5** is a cross-sectional view illustrating a magnetic path of a boss portion per pole; and

FIG. **6** is a schematic view showing a relationship between a claw pole and teeth of the stator core.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

An AC generator for a vehicle according to the present invention is described next.

The AC generator **1** for a vehicle according to an embodiment of the present invention is composed of a front frame **2**, rear frame **3**, an end cover **4**, a rotor and stator.

The front frame **2** and the rear frame **3** are made of aluminum die-cast and meet together at the outer open ends. They are fixed by a plurality of stad bolts **5** and nuts **6**.

The end cover **4** is fixed to the rear frame **3** and covers a brush unit fixed to a portion outside the rear frame **3**, a voltage regulator (not shown) and a rectifier unit **7**.

The rotor is composed of a shaft **9** to which engine rotation is transmitted through a pulley **8**, a pair of Lundell-type pole cores **10** press-fitted to the shaft **9**, a field coil **11** wound in the pole cores **10** and a plurality of permanent magnets **12** installed into the cores **10**.

The shaft **9** is rotatably supported through bearings **13** and **14** by respective boss portions **2**a and **3**a of the front frame **2** and the rear frame **3**. The pulley **8** is fitted to an end of the shaft outside the front frame **2** and fastened by a lock nut **15**.

A pair of the pole cores **10** has a cylindrical boss portion **10***a*, a plurality of claw poles **10***b* and disk portions **10***c* connecting the boss portions **10**a and each of the claw poles **10**b. Cylindrical boss portion **10**a extends radially between, i.e., is bounded radially by, field coil **11** and shaft **9**. The pole cores **10** are press-fitted to the shaft **9** from opposite sides in the axial direction so that each claw pole of one of the pole cores extends between two claw poles of the other pole core over the field coil. Each of the claw poles has trapezoidal peripheral surface tapering toward the edge as shown in FIG. **6**. Two cooling fans **16** are fixed by welding or the like to the opposite axial ends of the pole cores **10** to generate cooling air when rotated.

The field coil **11** is electrically connected to a pair of slip rings **17**, which is carried by the shaft **9**, through lead wires **11**a and **11**b and is supplied with the field current from a battery (not shown) through a pair of brushes **18** sliding on the slip rings **17**. When the field current is supplied to the field coil **11**, all the claw poles **10**b of one of the pole cores **10**A are magnetized to S-pole and all the claw poles **10**b of the other pole core **10**B are magnetized to N-pole.

The brush unit is composed of the brushes **18**, springs **19** biasing the brushes **18** against the outer periphery of the slip rings **17**, a brush holder **20** holding the brushes **18** and the spring **19** therein and a slip ring cover **21** covering the circumference of the slip ring **17**.

The stator is composed of a stator core **22** press-fitted into the inner periphery of the front frame **2** and an armature winding disposed in the stator core **22**.

The stator core **22** is composed of annular laminated-steel-plates having numbers of teeth **22**a as shown in FIGS. **5** and **6** formed on the inner periphery thereof to face the outer peripheries of the claw poles **10**b.

The stator winding **23** has Y-connected or Δ-connected three-separate-coils disposed in slots between the teeth **22**a of the stator core **22** as shown in FIGS. **5** and **6** and generates AC voltage when rotor rotates.

The permanent magnets **12** are sintered ferrite magnets and are disposed between opposite side-surfaces **10**d of the adjacent claw poles **10**b in the rotating direction by a bond or the like. They are magnetized to have the same pole as the facing side-surface of the claw poles as shown in FIGS. **5** and **6**.

As shown in FIG. **2**, because the main magnetic flux **Φ1** is generated at the boss portion **10**a by the field coil **11** in a direction opposite to the magnetic flux **Φ2** generated by the permanent magnet **12**, the magnetic flux Φa (that is, **Φ1–Φ2**) passing through the boss portion **10**a becomes smaller than the main flux **Φ1**. Thus, the cross-sectional area Sa of the magnetic-path per pole of the boss portion **10**a can be made smaller than the cross-sectional area of the same magnetic path without permanent magnets. In the meantime, the number of magnetic poles corresponds to the number of claw poles **10**b in this embodiment. That is, if the Lundell-type cores **10** have six claw poles, the number of poles is “6”.

On the other hand, an effective magnetic flux Φd reaches the teeth **22**a of the stator core **22** from the peripheral surface **10**h of the claw poles **10**b. The magnetic flux, before reaching the teeth, is reduced from the main magnetic flux **Φ1** by the leakage flux ΦL (leakage magnetic flux between the edge portion **10**e as well as the inner periphery **10**f of the claw poles **10**b and the outer periphery of the boss portion **10**a) and increased by the magnetic flux **Φ3** of the permanent magnet **12**. Thus, an amount of the magnetic flux passing the peripheral surfaces **10**h of the claw poles **10**b or the effective magnetic flux Φd is larger than the amount without the permanent magnets **12**. Therefore, the peripheral surface area Sd of the claw poles **10**b facing the teeth **22**a is designed to be wider than the peripheral surface area without the permanent magnets **12**.

A ratio between the cross-sectional area Sa of the magnetic path of the boss portion **10**a per pole and the peripheral surface area Sd of the portions of one of the claw poles **10**b facing are directly opposite the teeth **22**a when the center of each magnet **12** is midway between two successive teeth **22**a is described next with reference to FIGS. **4**, **5** and **6**.

The graph shown in FIG. **4** is obtained by using two kinds of permanent magnets and a pole core which have the following characteristics.

material of the permanent magnet:

(1) sintered ferrite magnet of Br:440 mT, H_{CB}:259 kA/m and BH_{MAX}:36.7kT/m^3

(2) molded ferrite magnet of Br:140 mT, H_{CB}:100 kA/m and BH_{MAX}:3.6 kT/m^3

size of the permanent magnet:

7.7 mm in width (disposed between the claw poles), 16 mm in length and 10 mm in depth

number of poles: 12

material of the pole core:

cold forged steel of B_{50}:1.68 T, Hc:200 kA/m

outer diameter of the pole core:90 mm

axial length of the pole core:40 mm

As the cross-sectional area Sa of the magnetic flux of the boss portion **10**a becomes smaller relative to the peripheral surface area Sd, the output power per weight of the rotor increases steeply if the sectional ratio (Sa / Sd) is not higher than 120%. The critical sectional ratio of 120% is the same either with the sintered ferrite magnets or with the molded ferrite magnets. The embodiment with the sintered ferrite magnets provides a maximum output power when the sectional ratio is 100%, which is 45% greater than the output power of a generator having a conventional rotor which has no permanent magnet.

On the other hand, it is necessary to prevent an excessive voltage caused by the magnetic flux **Φ3** of the permanent magnets **12** when no field current is supplied because such excessive voltage is detrimental to the battery. For this purpose, the magnetic saturation degree of the boss portion **10**a is designed to be smaller than the magnetic saturation degree of the peripheral surface area Sd of the claw poles **10**b. In order to decrease the magnetic flux **Φ3**, the ratio of the cross-sectional area Sa of the magnetic path to the cross-sectional area Sd of the claw poles **10**b, that is, (Sa / Sd) should be no less than 70%. Because the embodiment has 100%-ratio of the cross-sectional areas, such excessive voltage is not generated.

Therefore, the output power of the rotor per weight increases and excessive voltage with no-field-current is prevented.

In the foregoing description of the present invention, the invention has been disclosed with reference to specific embodiments thereof. It will, however, be evident that various modifications and changes may be made to the specific embodiments of the present invention without departing from the broader spirit and scope of the invention as set forth in the appended claims. Accordingly, the description of the present invention in this document is to be regarded in an illustrative, rather than restrictive, sense.

What is claimed is:

1. An AC generator for a vehicle having a combined structure of a field coil and a permanent magnet, said AC generator comprising:

a stator having a stator core with a plurality of teeth formed on a inner periphery thereof and a stator winding disposed between said teeth; and a rotor rotatably disposed inside said stator, in said rotor having a rotor shaft, a magnetic boss portion on which said field coil is wound, said magnetic boss portion being carried by said rotor shaft and being bounded radially by said rotor shaft and said field coil, a plurality of claw poles extending from opposite sides of said boss portion to face said teeth to provide a magnetic field, and a permanent magnet disposed between said claw poles; wherein

said boss portion has a cross-sectional area Sa per pole perpendicular to the magnetic path of magnetic flux generate by said field coil and said permanent magnet,

each of said claw poles has a peripheral surface, said peripheral surface having portions which are directly opposite said teeth when each said permanent magnet is centered midway between two successive teeth, and the portions having a total area Sd, and

a ratio Sa/Sd is between 70% and 120%.

2. An AC generator as claimed in claim **1**, wherein said ratio is approximately 100%.

3. An AC generator as claimed in claim **1**, wherein said permanent magnet comprises a sintered ferrite magnet.

4. An AC generator as claimed in claim **1**, wherein said permanent magnet comprises a molded ferrite magnet.

5. An AC generator as claimed in any one of claims **1**, wherein

each of said claw poles of said pole core comprises an approximately a trapezoidal peripheral surface facing said teeth.

6. An AC generator as claimed in claim **1**, wherein said permanent magnet is disposed radially spaced apart from said field coil.

7. An AC generator as claimed in claim **1**, wherein

said rotor further has a pair of disc portions at opposite sides of said boss portion between said boss portion and said claw poles, and

said field coil is in close contact with said opposite disk portions.

* * * * *